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Division of Materials Chemistry
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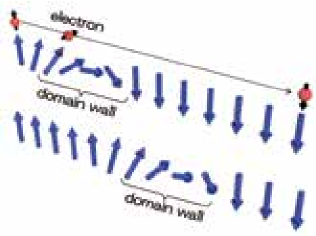
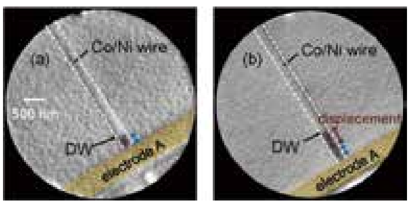
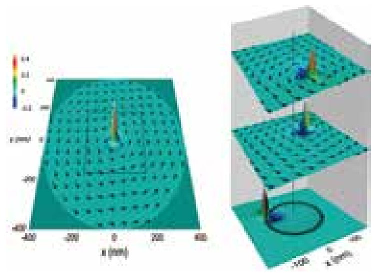
Scope of Research

Conventional electronics uses only the charge of electrons, while traditional magnetic devices use only the spin degree of freedom of electrons. Aiming at complete control of both charge and spin in single solid-state devices, an emerging field called spintronics is rapidly developing and having an impact on information technologies. By combining the atomic-layer deposition with nanofabrication, we focus on the development of spin properties of various materials and the control of quantum effects in mesoscopic systems for novel spintronics devices.

KEYWORDS
Spintronics
Quantum Transport
Nano-fabrication
Artificial Materials







Selected Publications

Moriyama, T.; Takei, S.; Nagata, M.; Yoshimura, Y.; Matsuzaki, N.; Terashima, T.; Tserkovnyak, Y.; Ono, T., Anti-damping Spin Transfer Torque through Epitaxial Nickel Oxide, *Appl. Phys. Lett.*, **106,** [162406-1]-[162406-4] (2015).

Yoshimura, Y.; Kim, K.-J.; Taniguchi, T.; Tono, T.; Ueda, K.; Hiramatsu, R.; Moriyama, T.; Yamada, K.; Nakatani, Y.; Ono, T., Soliton-like Magnetic Domain Wall Motion Induced by the Interfacial Dzyaloshinskii–Moriya Interaction, *Nat. Phys.*, doi:10.1038/nphys3535 (2015)(in press).

Matsuo, S.; Takeshita, S.; Tanaka, T.; Nakaharai, S.; Tsukagoshi, K.; Moriyama, T.; Ono, T.; Kobayashi, K., Edge Mixing Dynamics in Graphene p–n Junctions in the Quantum Hall Regime, *Nat. Commun.*, **6,** [8066-1]-[8066-6] (2015).

Tanabe, K.; Matsumoto, R.; Ohe, J.; Murakami, S.; Moriyama, T.; Chiba, D.; Kobayashi, K.; Ono, T., Real-time Observation of Snell's Law for Spin Waves in Thin Ferromagnetic Films, *Applied Physics Express*, **7,** [053001-1]-[053001-4] (2014).

Chiba, D.; Fukami, S.; Shimamura, K.; Ishiwata, N.; Kobayashi, K.; Ono, T., Electrical Control of the Ferromagnetic Phase Transition in Cobalt at Room Temperature, *Nature Materials*, **10,** 853-856 (2011).

Soliton-like Magnetic Domain Wall Motion Induced by the Interfacial Dzyaloshinskii-Moriya Interaction

Topological spin structures such as magnetic domain walls (DWs), vortices, and skyrmions often appear in magnetic materials. Since the stability of spin structure is strongly protected by its topological nature, such topological objects can be exploited in the production of memory devices. Recently, a novel type of antisymmetric exchange interaction, namely Dzyaloshinskii-Moriya interaction (DMI), has been uncovered and found to influence the formation of topological objects. Exploring how DMI affects the dynamics of topological objects is therefore an important task. Here we investigate experimentally the dynamics of the magnetic DW under DMI and found that DMI boosts DW velocity. Furthermore, enhanced DW velocity is maintained at a constant for a wide range of magnetic fields. Such distinct behavior of DW velocity can be explained in terms of a magnetic soliton with its topology protected during its motion. Our results therefore shed light on the physics of dynamic topological objects, paving the way for future work in topology-based memory applications.

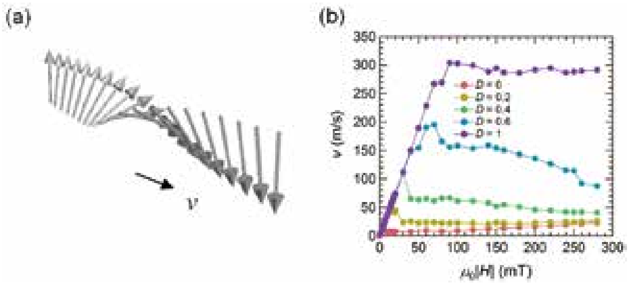


Figure 1. Magnetic soliton and its velocity. (a) Topologically protected magnetic soliton spin structure. (b) Magnetic soliton velocity v as a function of magnetic field $\mu_0 H$. Different colors correspond to different strengths of the Dzyaloshinskii-Moriya interaction D as denoted in the legend. The units of D are mJ/m^2.

Anti-damping Spin Transfer Torque through Antiferromagnetic Material

Spin transfer torque (STT) has been an efficient and promising technique to control magnetization of ferromagnetic materials in modern spintronic devices. This novel technique is based on an interaction between electron spin and local magnetic moments. The same interaction should be conserved in antiferromagnets in which there are microscopic local magnetic moments that compensate each other to exhibit no net magnetization. In this work, we prepared MgO(001) substrate / Pt 5nm / NiO 10nm / FeNi 3nm / SiO2 5nm multilayers, in which the films are epitaxially grown until the NiO layer, and performed a spin torque ferromagnetic resonance (ST-FMR) measurement to quantify the anti-damping spin torque transported between the Pt and the FeNi through the antiferromagnetic NiO layer. A pure spin current is created by the spin Hall effect of the Pt and injected into the NiO. As shown in Figure 2(a), we found that the FMR linewidth monotonously varies with the spin current injection. As the ST-FMR measurement is only sensitive to the linewidth (i.e., magnetic damping) of the FeNi layer, this change in the linewidth in Pt/NiO/FeNi can be interpreted in a way that the spin current is transferred through the NiO and interacts with the FeNi. This intriguing spin current transport can be explained by the angular-momentum transfer mediated by the antiferromagnetic magnons as shown in Figure 2(b). Our results assure that the spin current exerts a spin torque on the NiO magnetic moments and excites their dynamics. The results open up a new field of antiferromagnetic spintronics.

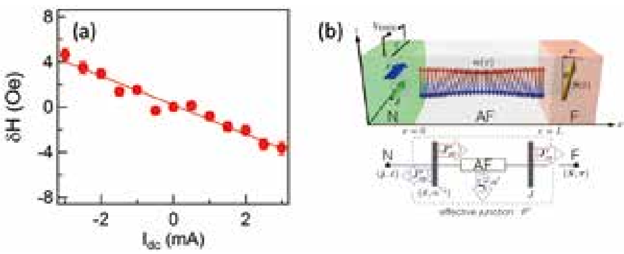


Figure 2. (a) FMR linewidth δH as a function of the dc current. Due to the spin Hall effect of Pt, the spin current injection is proportional to the dc current. (b) Schematic illustration of the N (Pt) / AF (NiO) / F (FeNi) structure in which the anti-damping spin transfer torque takes place. N (Pt) layer injects the spin current J^s_{stt} toward AF (NiO). The antiferromagnetic magnon in AF (NiO) carries the spin current J^s_{ex} toward F (FeNi).